



Original Communication

## Age-at-death estimation based on the macroscopic examination of Spheno-occipital sutures

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### ABSTRACT

**Objective:** To examine the closure degree of spheno-occipital synchondrosis and its relationship with chronological age.

**Materials and Methods:** Cross-sectional analysis of the closure degree of spheno-occipital suture was done through direct inspection of 376 autopsies from both sexes whose ages ranged between 8 and 26 years in Legal Medicine Organization of Tehran, Iran from 1st of July 2007 to 1st of July 2009. The correlation between the degree of closure and chronological age was investigated.

**Results:** Mean ages of open, semi-closed and closed sutures were 12.27, 16.12 and 21.17 years in males, and 9.04, 12.38 and 19.44 in females, respectively. Seemingly, their difference was significant ( $p < 0.001$ ). Partial fusion (semi-closed) was seen at the age of 12 in both sexes while complete fusion (closed) was seen at 15 year olds or above in males and 12 year olds or above in females. Spearman's correlation ratio coefficient showed a linear correlation between age and suture situation in both sexes ( $\rho = 0.788$ ,  $P < 0.001$  in males and  $r = 0.645$ ,  $P < 0.001$  in females).

**Conclusion:** The study showed that the closure degree of spheno-occipital suture can be used as a good indicator for age estimation in both sexes. Cadavers can be correctly grouped above or below 16 years old with sensitivity of 79.82% and specificity of 89.47% in males and above or below 13 years old with sensitivity of 100.00% and specificity of 81.58% in females.

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### 1. Introduction

Age estimation is one of the consequential factors which improve identification. The assessment of biological age is generally more precise in the early phases of development and extremely based on the state of conservation diagnostic features in the remnants. With naked eye, two forms of variables are useful indicators of biological age: dental development and epiphyseal closure in some parts of the skeleton.

Determination of age at the time of death based on the observation of cranial sutures has led to numerous studies with sometimes contradictory results. One of the features being recommended as a good age indicator is the state of fusion of the spheno-occipital

synchondrosis, despite the fact that there are different ideas about its reliability.<sup>1</sup> Seemingly, the disagreements in the reported degree of the sutures closure are related in some degree to the methods of assessment, *i.e.*, direct inspection, imaging or histological examination and to the discipline of the investigator, *i.e.*, forensic pathology or anatomy.<sup>2</sup> Also very likely ethical and genetic factors have a significant role in determining cranial suture patterns and closure.<sup>3–5</sup> In this study we investigated the closure degree of the synchondrosis to verify its validity as an indicator of biological age in Tehran residents of Iranian population.

### 2. Materials and methods

#### 2.1. Study design

Cross-sectional analysis was done about the usefulness of the closure degree of the Spheno-occipital suture in order to estimate the age-at-death of the decedents.

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## 2.2. Setting and population

The study was conducted within the framework of the Tehran's Legal Medicine Organization (LMO), the largest Iran's LMO that serves about 20% of the Iran's population.<sup>6–11</sup> The closure stage of the basilar synchondrosis of 376 fresh cadavers with known chronological age was assessed during autopsy. The sample included from 8 to 26 years old cadavers of both sexes that had been referred to Tehran's LMO during 1st July 2007 until 1st July 2009.

Macroscopically the sutures were examined and found to be generally symmetrical in appearance. The macroscopic study was carried out by unique examiners, without previous knowledge of the age of the cadavers. During a routine forensic autopsy, the calvarium was removed with the help of an electric saw and brain taken out after dividing medulla just below the foramen magnum. The state of the suture was examined after removal of the covering of dura matter completely from the surface of the endocranum, between the rostral margin of the foramen magnum, through the body of the sphenoid bone and the Clinoid anterior processes.<sup>1,2</sup> The length of the cartilaginous part of the suture was measured and its consistency was examined with scalpel. They were divided to three groups: 1) Open: suture was open or less than 1/4 had been calcified. 2) Semi-closed: more than 1/4 and less than 3/4 of the cartilage had been calcified. 3) Closed: more than 3/4 had been calcified. Regression analysis was carried out taking age as a dependent variable (Y) and degree of fusion (open = 0, semi-closed = 1 and closed = 2) as an independent variable (X).

## 2.3. Data collection

We excluded decedents displaying modifications of the cranium or developmental abnormalities (asymmetry, bone destruction due to serious trauma or carbonization) or any underlying bone pathology (such as punched-out lesions or internal frontal hyperostosis). Apart from the previously mentioned bone defects, the cause of death was not a criterion to select individuals. All cases were Iranian residents of Tehran with known chronological ages.

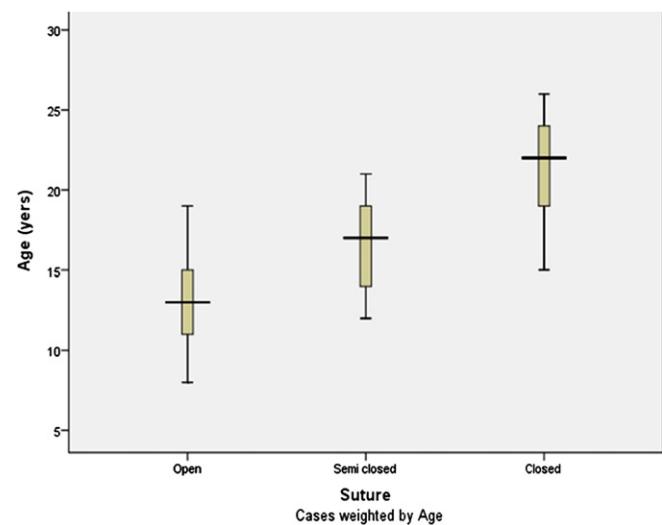
## 2.4. Data analysis

The statistical analysis was conducted on SPSS for Windows 16. Then we established a model of linear regression which could easily

**Table 1**

Spheno-occipital suture status in males by age.

| Age (years) | Suture |             |        | Total |
|-------------|--------|-------------|--------|-------|
|             | Open   | Semi-closed | Closed |       |
| 8           | 4      | 0           | 0      | 4     |
| 9           | 4      | 0           | 0      | 4     |
| 10          | 6      | 0           | 0      | 6     |
| 11          | 6      | 0           | 0      | 6     |
| 12          | 8      | 3           | 0      | 11    |
| 13          | 7      | 4           | 0      | 11    |
| 14          | 6      | 6           | 0      | 12    |
| 15          | 3      | 6           | 1      | 10    |
| 16          | 2      | 3           | 7      | 12    |
| 17          | 1      | 5           | 7      | 13    |
| 18          | 0      | 5           | 11     | 16    |
| 19          | 1      | 4           | 7      | 12    |
| 20          | 0      | 4           | 10     | 14    |
| 21          | 0      | 3           | 8      | 11    |
| 22          | 0      | 0           | 8      | 8     |
| 23          | 0      | 0           | 11     | 11    |
| 24          | 0      | 0           | 11     | 11    |
| 25          | 0      | 0           | 10     | 10    |
| 26          | 0      | 0           | 8      | 8     |
| Total       | 48     | 43          | 99     | 190   |



**Fig. 1.** Box-Plot of spheno-occipital suture status in male cadavers by age.

be used routinely to predict the age-at-death of 8–26 Y/O individual, based on the stage of closure being evaluated macroscopically and on known sex cadavers (age is thus considered as the dependent variable).

## 3. Results

The sample included 376 cadavers (190 males and 186 females) whose ages ranged from 8 to 26 years.

### 3.1. Male cadavers

Age distribution and their suture situation in male cadavers are shown in Table 1 and Fig. 1. With regard to male cadavers, 48 cases had open suture. The mean age of male cadavers with open suture was 12.27 years (SD: 2.73). Maximum age in group with open suture was 19 years. Forty-three male cases had semi-closed suture that their mean age was 16.12 (SD: 2.85). In the group with semi-closed suture minimum and maximum ages were 12 and 21 years respectively. Ninety-nine male cases had closed suture. Mean age of male cadavers with closed suture was 21.17 (SD: 3.14). The lowest age in closed suture group was 15 years (Table 2).

One-way ANOVA showed significant difference between age and suture closure in male group ( $P < 0.001$ ). Spearman's correlation ratio coefficient showed linear correlation between age and suture closure ( $P < 0.001$ , rho = 0.788). Regression analysis was carried out taking age as a dependent variable (Y) and degree of fusion (open = 0, semi-closed = 1 and closed = 2) as an independent variable (X). Linear regression gave the following formula for age prediction:  $Y = 12.07 + 4.50 \times X (R^2 = 0.618)$ . Linear regression parameters for prediction of age in male cadavers by Spheno-occipital suture closure status are shown in Table 3. Thus the mean age of male cadavers with open Spheno-occipital suture was 12.1

**Table 2**

Descriptive means of age in different male groups by closure state of spheno-occipital suture.

| Suture closure status | Mean age (years) | N   | SD   | SE of mean | Min | Max | Range |
|-----------------------|------------------|-----|------|------------|-----|-----|-------|
| Open                  | 12.27            | 48  | 2.73 | 0.395      | 8   | 19  | 11    |
| Semi-closed           | 16.12            | 43  | 2.85 | 0.434      | 12  | 21  | 9     |
| Closed                | 21.17            | 99  | 3.14 | 0.316      | 15  | 26  | 11    |
| Total                 | 17.78            | 190 | 4.81 | 0.349      | 8   | 26  | 18    |

**Table 3**

Linear regression parameters for prediction of age in male cadavers by Spheno-occipital suture closure status.

| Coefficients <sup>a</sup> |                       | Unstandardized coefficients |            | Standardized coefficients |  | t      | Sig.  | 95% Confidence interval for B |             |
|---------------------------|-----------------------|-----------------------------|------------|---------------------------|--|--------|-------|-------------------------------|-------------|
| Model                     |                       | B                           | Std. error | Beta                      |  |        |       | Lower bound                   | Upper bound |
| 1                         | (Constant)            | 12.067                      | 0.393      |                           |  | 30.738 | 0.000 | 11.293                        | 12.842      |
|                           | Suture closure status | 4.503                       | 0.258      | 0.786                     |  | 17.434 | 0.000 | 3.993                         | 5.012       |

<sup>a</sup> Dependent variable: Age (years).

years (with 95% confidence interval 11.3–12.8 years). The mean age of male cadavers with semi-closed Spheno-occipital suture was 16.6 years (with 95% confidence interval 12.6–21.6 years). Also the mean age of male cadavers with closed Spheno-occipital suture was 21.1 years (with 95% confidence interval 17.1–26.1 years). With sensitivity of 79.82% and specificity of 89.47%, males can be correctly grouped above or below 16 years old.

### 3.2. Female cadavers

Age distribution and suture status of female cadavers are shown in Table 4 and Fig. 2. With regard to female cadavers, 23 cases had open suture. The mean age of female cadavers with open suture was 9.04 years (SD: 1.15). Maximum age in group with open suture was 11 years. Eight female cases had semi-closed suture that their mean age was 12.38 (SD: 0.52). In group with semi-closed suture, minimum and maximum ages were 12 and 13 years respectively. One hundred fifty five female cases had closed suture. Mean age of female cadavers with closed suture was 19.44 (SD: 3.59). The lowest age in closed suture group was 12 years (Table 5).

One-way ANOVA showed a significant difference between age and suture closure in the female group ( $P < 0.001$ ). Spearman's correlation ratio coefficient showed linear correlation between age and suture closure ( $P < 0.001$ , rho = 0.645). Regression analysis was carried out taking age as a dependent variable (Y) and degree of fusion (open = 0, semi-closed = 1 and closed = 2) as an independent variable (X). Linear regression gave the following formula for age prediction:  $Y = 8.75 + 5.32 \times X (R^2 = 0.540)$ . Linear regression parameters for prediction of age in female cadavers by Spheno-occipital suture closure status are shown in Table 6. Thus the mean

age of female cadavers with open Spheno-occipital suture was 8.7 years (with 95% confidence interval 7.4–10.1 years). The mean age of female cadavers with semi-closed Spheno-occipital suture was 14.1 years (with 95% confidence interval 9.5–20.1 years). Also the mean age of female cadavers with closed Spheno-occipital suture was 19.3 years (with 95% confidence interval 14.7–25.3 years). With sensitivity of 100.00% and specificity of 81.58% females can be correctly grouped above or below 13 years old.

## 4. Discussion

In the perfect cadavers depending on the developmental phase including prenatal, childhood, adolescence and adulthood, different parameters can be used for age estimation. Using multiple age indicators make age estimation more accurate.<sup>1,12</sup> But occasionally there are only remnants of cadaver or skeleton. In this situation accuracy of age estimation greatly depends on the state of preservation of diagnostic features in the remnants.

In forensic or anthropological practice, the degree of closure of cranial sutures is widely used in various methods of age determination. The stage of fusion of the basilar synchondrosis (spheno-occipital fissure) has been regarded as a trustworthy indicator of biological age.<sup>12,13</sup> Several investigators suggest that the synchondrosis stays open throughout childhood and adolescence and merges as the individual reaches adulthood.<sup>14–21</sup> A second group suggests that coalescence begins during the adolescent stage concurrent with eruption of the second permanent molars.<sup>5,22–28</sup> Frick et al. reported a wide variation in the fusion of this feature.<sup>29</sup> In another study Sahni et al. showed that in the male if a complete fusion occurs, the age of the boy will be 15 years or above. They also showed that in the cases where there is no fusion

**Table 4**  
Spheno-occipital suture stage in females by age.

| Age (years) | Suture |             |        | Total |
|-------------|--------|-------------|--------|-------|
|             | Open   | Semi-closed | Closed |       |
| 8           | 10     | 0           | 0      | 10    |
| 9           | 6      | 0           | 0      | 6     |
| 10          | 3      | 0           | 0      | 3     |
| 11          | 4      | 0           | 0      | 4     |
| 12          | 0      | 5           | 2      | 7     |
| 13          | 0      | 3           | 5      | 8     |
| 14          | 0      | 0           | 10     | 10    |
| 15          | 0      | 0           | 8      | 8     |
| 16          | 0      | 0           | 8      | 8     |
| 17          | 0      | 0           | 21     | 21    |
| 18          | 0      | 0           | 14     | 14    |
| 19          | 0      | 0           | 7      | 7     |
| 20          | 0      | 0           | 14     | 14    |
| 21          | 0      | 0           | 13     | 13    |
| 22          | 0      | 0           | 15     | 15    |
| 23          | 0      | 0           | 18     | 18    |
| 24          | 0      | 0           | 8      | 8     |
| 25          | 0      | 0           | 7      | 7     |
| 26          | 0      | 0           | 5      | 5     |
| Total       | 23     | 8           | 155    | 186   |

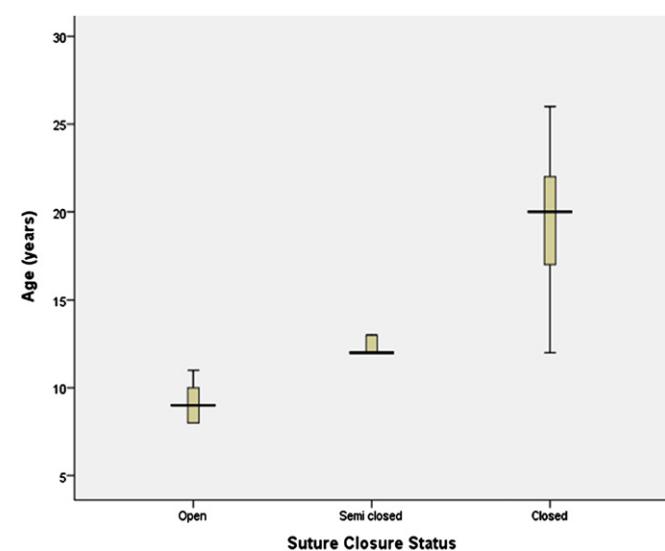


Fig. 2. Box-Plot of spheno-occipital suture status in female cadavers by age.

**Table 5**

Descriptive means of age in different female groups by closure state of spheno-occipital suture.

| Suture closure status | Mean age | N   | SD   | SE of mean | Min | Max | Range |
|-----------------------|----------|-----|------|------------|-----|-----|-------|
| Open                  | 9.04     | 23  | 1.15 | 0.239      | 8   | 11  | 3     |
| Semi-closed           | 12.38    | 8   | 0.52 | 0.183      | 12  | 13  | 1     |
| Closed                | 19.44    | 155 | 3.59 | 0.288      | 12  | 26  | 14    |
| Total                 | 17.85    | 186 | 4.89 | 0.359      | 8   | 26  | 18    |

**Table 6**

Linear regression parameters for prediction of age in female cadavers by Spheno-occipital suture closure status.

| Coefficients <sup>a</sup> |                       |                             |                           | t     | Sig.   | 95% Confidence interval for B |             |        |
|---------------------------|-----------------------|-----------------------------|---------------------------|-------|--------|-------------------------------|-------------|--------|
| Model                     |                       | Unstandardized coefficients | Standardized coefficients |       |        | Lower bound                   | Upper bound |        |
|                           |                       | B                           | Std. error                | Beta  |        |                               |             |        |
| 1                         | (Constant)            | 8.748                       | 0.666                     |       | 13.136 | 0.000                         | 7.434       | 10.062 |
|                           | Suture closure status | 5.323                       | 0.362                     | 0.735 | 14.687 | 0.000                         | 4.608       | 6.038  |

<sup>a</sup> Dependent variable: Age (years).

or partial fusion, he should be below the age of 19. Finally, in the case of females, fusion occurs between the age of 13 and 17.<sup>30</sup> But Kahana et al. found no correlation between chronological age and the closure degree of the synchondrosis in males, although in females they found it a possible reliable indicator of age but they had a small sample comprising of 21 females.<sup>2</sup>

We tried to examine a large sample of both sexes in this study. Our results showed that the closure degree of Spheno-occipital suture has a linear correlation with age. Mean ages of open, semi-closed and closed suture groups were significantly different in both sexes. In male cadavers when the suture is closed, age is 15 years or above and when the suture is open or semi-closed, age is below 21 years. In female cadavers when the suture is closed, age is 12 years or above and where the suture is open or semi-closed, age is 13 years or below. With a relative high sensitivity and specificity we can divide males above and below 16 years according to the suture closure degree (open and semi-closed are considered open). With higher sensitivity and nearly equal specificity we can divide females above and below 13 years old according to the suture closure degree.

Our work showed that the observation of the closure degree of just one suture, the Spheno-occipital one, allows the age prediction of mature individuals. Thus there exists a statistical link between age and the degree of suture closure. This statistical link is important and precise in our study as shown by the confidence interval of this parameter and the sensitivity and specificity of the formula. The results of this study were similar to our previous study which was done on a smaller sample during 2004–2005.<sup>1</sup> Our results are also compatible with Frick et al. and Sahni et al. findings.<sup>29,30</sup> Ethnical differences that have been among Kahana et al. materials may be responsible to their wide discrepancy of synchondrosis fusion time.<sup>2</sup>

We examined the state of fusion of the basilar synchondrosis as a biological age indicator in a sample of 376 cadavers of both sexes whose ages ranged between 8 and 26 years. Our findings indicated that the stage of fusion of the basilar synchondrosis can be a useful indicator of age in male and female cadavers, when estimating age of unknown human remains, although further investigation on different ethnic population is recommended. Legal Medicine Organization of Iran with more than 1.5 million forensic referrals and 50 000 autopsies per year is an appropriate field for such researches and trainings.<sup>6–11,31–33</sup>

#### Conflict of interests

We have no competing interests.

#### Funding

We had no financial support for this research. The research was done during routine forensic autopsies on the fresh cadavers referred to Tehran's LMO.

#### Ethical approval

None.

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